TECHNICAL REPORT

Contract Title:	Infrared Algorithm Development for Ocean Observations with EOS/MODIS
Contract:	NAS5-31361
Type of Report:	Semi-Annual
Time Period:	January-June 1998
Principal Investigator:	Otis B. Brown RSMAS/MPO University of Miami 4600 Rickenbacker Causeway Miami, Florida 33149-1098

INFRARED ALGORITHM DEVELOPMENT FOR OCEAN OBSERVATIONS WITH EOS/MODIS

Abstract

Efforts continue under this contract to develop algorithms for the computation of sea surface temperature (SST) from MODIS infrared measurements. These include radiative transfer modeling, comparison of *in situ* and satellite observations, development and evaluation of processing and networking methodologies for algorithm computation and data accession, evaluation of surface validation approaches for IR radiances, development of experimental instrumentation, and participation in MODIS (project) related activities. Activities in this contract period have focused on field campaigns, analysis of field data and the organization of and participation in two workshops held at RSMAS in early March.

MODIS INFRARED ALGORITHM DEVELOPMENT

A. Near Term Objectives

A.1. Continue algorithmic development efforts based on experimental match-up databases and radiative transfer models.

A.2. Continue interaction with the MODIS Instrument Team through meetings and electronic communications, and provide support for MCST pre-launch calibration activities.

A.3 Continue evaluation of different approaches for global SST data assimilation and work on statistically based objective analysis approaches.

A.4 Continue evaluation of high-speed network interconnection technologies.

A.5 Continue development of *in situ* validation approaches for the MODIS IR bands.

A.6 Provide investigator and staff support for the preceding items.

B. Overview of Current Progress

B.1 January-June 1998

Activities during the past six months have continued on the previously initiated tasks. There have been specific efforts in the areas of (a) IR calibration/validation as part of the MODIS Ocean Science Team cruise effort, (b) the organization and participation of two workshops in Miami to compare the quantitative performance of diverse infrared radiometers and to coordinate future validation campaigns; and to (c) test and evaluation of an experimental wide area network based on

ATM technology. In addition, previously initiated activities such as team related activities continue.

Special foci during this six-month period have been:

1) Continue analysis of measurements from the DOE/NOAA/NASA ARM Combined Sensor Project cruise in the Tropical Western Pacific in the spring of 1996 and from the cruise of the *R/V Roger Revelle* in the Pacific Ocean in the autumn of 1997.
2) Participation in a research cruise at 24°N in the Atlantic Ocean on the *NOAA S Ronald H. Brown.*
3) Preparations and participation in the research cruise to the Canadian Arctic on the *CCGS Pierre Radisson.*
4) Preparation and participation in the Ocean-Atmosphere Carbon Exchange Study cruise in the North Atlantic Ocean on the *NOAA S Ronald H. Brown.*
5) Refinement of marine FTIR instrumentation for cal/val applications by UW/SSEC through a subcontract.
6) Organization and participation in the Miami IR Workshops.
7) Continue negotiations for ship-time for post-launch validation, and explore options for long-term validation from fixed platforms.
8) Wide area networking.

B.1.1 Combined Sensor Cruise of the NOAA S *Discoverer* & the Pacific Section on the *R/V Revelle*

As described in earlier reports, the Combined Sensor Cruise in the Tropical Western Pacific in March–April 1996, generated an unprecedented array of measurements of atmospheric boundary layer variables and sea surface temperature. Analysis of the prototype M-AERI data continues with emphasis on the response of the thermal skin layer to changes in the air-sea heat fluxes.

The measurements from the *Revelle* cruise from Hawaii to New Zealand, reported upon in the last semi-annual report, have undergone quality control and are now the subject of more detailed analysis.

B.1.2 The 24°N Atlantic Sections on the *NOAA S Ronald H. Brown*

Background

The NOAA Atlantic Oceanographic and Meteorological Laboratory offered ship time and berths on the NOAA's Ronald Brown on the Trans-Atlantic sections between Miami and the Canary Islands. This was offered as a cooperative venture with NOAA providing travel support for the two participants on the second, one-month leg from Las Palmas to Miami.

Details of the ship can be found at the URL http://www.pmc.noaa.gov/rb/ and of the cruise at URL http://www.aoml.noaa.gov/phod/24n. The cruise track is shown in Figure 1.

Objectives

To gain more ship-time experience with M-AERI's prior to the EOS-AM Launch; to gather data for the study of the thermal skin effect at the ocean surface, and b) diurnal temperature signals; to test satellite validation schemes using data from the AVHRR.

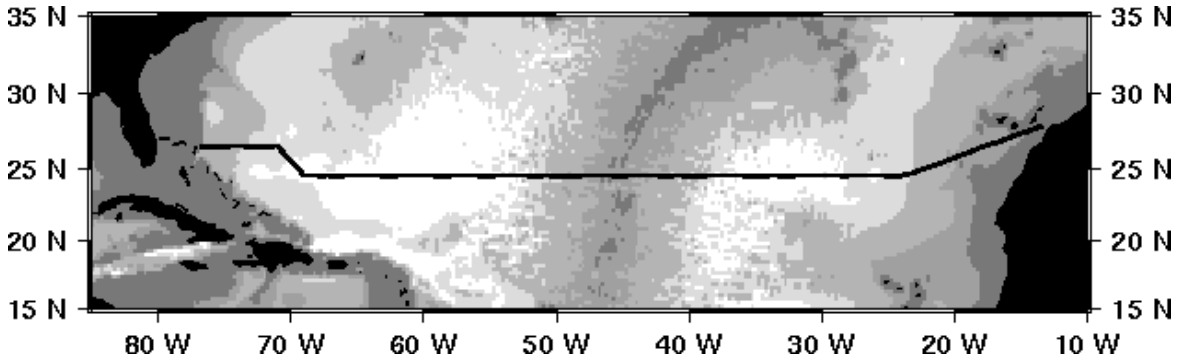

Figure 1. Track of the NOAA S Ronald H. Brown along the 24oN sections. The section was completed twice: first going east, then going west.

Personnel involved

A. Cruise Leg 1 from Miami to Las Palmas	Ms. J. Hanafin and Ms. E. Key
B. Cruise Leg 2 from Las Palmas to Miami (with NOAA support)	Dr. R. Sikorski and Ms. Deanna Wilson-Diaz
C. In-port instrument maintenance in Las Palmas	Dr. P. J. Minnett

Narrative:

The NOAA Ship *Ronald H. Brown* sailed from Miami on January 8 and progressed along a section at about 24°N, arriving in Las Palmas on January 21. After two days in port, the ship returned to Miami, arriving on February 24. The outward journey involved measurements taken with the ship underway, and the return journey included 127 oceanographic stations.

The Marine-Atmospheric Emitted Radiance Interferometer (M-AERI-01) was embarked on the ship in Miami, together with a Coastal Environmental Systems "Weatherpak" boundary-layer meteorological station, an all-sky camera and an *in-situ* SST float. This float, which takes measurements at a depth of a few centimeters was deployed on the second leg during the oceanographic stations. NOAA supplied radiosondes. AVHRR data were supplied by the University of La Laguna, Tenerife, Canary Islands, which has an HRPT receiving station.

The M-AERI was mounted on the 02 deck forward (Figure 2). At this position the M-AERI could view the sea-surface ahead of the bow wave in water undisturbed by the presence of the ship. The instrument took measurements at zenith and at 55° to zenith and nadir. Apart from periods when it was covered to avoid contamination of the scan mirror by sea-spray in conditions of high winds, the M-AERI operated continuously.

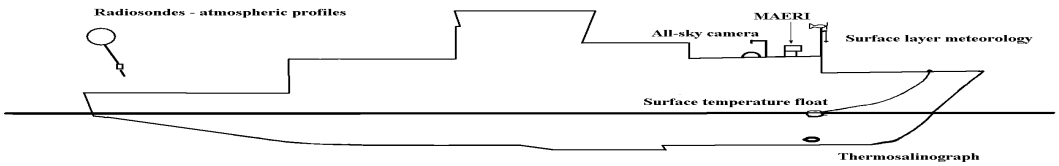

Figure 2. Layout of instruments on the NOAA S Ronald H. Brown.

A list of radiosonde launches is given in Table 1 and of AVHRR images supplied by the University of La Laguna in Table 2. AVHRR images over the western part of the ship's track will be extracted from the AVHRR data archive at RSMAS.

Table 1. Time and positions of radiosonde launches. Cruise of the NOAA S *Ronald H. Brown*, 24^{0}N Sections

9 January 98 11:7 GMT	25.90 N	78.00 W
9 January 98 22:39 GMT	26.50 N	75.80 W
10 January 98 10:45 GMT	26.50 N	73.00 W
10 January 98 22:40 GMT	25.90 N	70.50 W
11 January 98 10:44 GMT	24.50 N	68.30 W
11 January 98 22:45 GMT	24.50 N	65.50 W
12 January 98 10:46 GMT	24.50 N	62.60 W
12 January 98 21:40 GMT	24.50 N	60.00 W
13 January 98 10:45 GMT	24.50 N	56.80 W
13 January 98 22:39 GMT	24.50 N	53.90 W
14 January 98 10:43 GMT	24.50 N	50.90 W
14 January 98 22:40 GMT	24.30 N	48.00 W
15 January 98 11:0 GMT	24.50 N	45.10 W
15 January 98 22:41 GMT	24.50 N	42.40 W
16 January 98 10:44 GMT	24.50 N	39.70 W
16 January 98 22:42 GMT	24.50 N	36.50 W
17 January 98 10:44 GMT	24.50 N	33.50 W
17 January 98 23:5 GMT	24.50 N	26.40 W
18 January 98 10:53 GMT	24.50 N	27.70 W
18 January 98 22:45 GMT	24.50 N	24.80 W
19 January 98 22:45 GMT	25.80 N	19.60 W
20 January 98 10:42 GMT	26.70 N	16.90 W
20 January 98 22:48 GMT	27.60 N	14.20 W
23 January 98 22:49 GMT	27.90 N	13.60 W
24 January 98 10:54 GMT	27.80 N	13.90 W
24 January 98 22:55 GMT	27.20 N	15.60 W
25 January 98 10:47 GMT	26.80 N	16.70 W
25 January 98 22:52 GMT	26.40 N	18.10 W
26 January 98 10:53 GMT	25.90 N	19.40 W
27 January 98 11:18 GMT	25.20 N	21.50 W
28 January 98 10:57 GMT	24.50 N	24.20 W
29 January 98 10:46 GMT	24.50 N	26.40 W
30 January 98 10:45 GMT	24.50 N	29.20 W
31 January 98 10:47 GMT	24.50 N	31.90 W
1 February 98 10:46 GMT	24.50 N	34.40 W
2 February 98 10:44 GMT	24.50 N	36.90 W
3 February 98 10:48 GMT	24.50 N	39.70 W
3 February 98 22:52 GMT	24.50 N	40.90 W
4 February 98 10:42 GMT	24.50 N	41.90 W
5 February 98 17:56 GMT	24.50 N	44.90 W
5 February 98 22:51 GMT	24.50 N	45.50 W
6 February 98 10:49 GMT	24.50 N	47.10 W
6 February 98 22:45 GMT	24.50 N	48.20 W
7 February 98 10:43 GMT	24.50 N	49.30 W
7 February 98 22:43 GMT	24.50 N	50.00 W
8 February 98 10:47 GMT	24.50 N	50.90 W
8 February 98 23:6 GMT	24.50 N	52.10 W
9 February 98 10:42 GMT	24.50 N	52.90 W
9 February 98 22:44 GMT	24.50 N	53.80 W
10 February 98 10:53 GMT	24.50 N	55.20 W
10 February 98 22:43 GMT	24.50 N	56.00 W
11 February 98 22:44 GMT	24.50 N	58.60 W
12 February 98 10:52 GMT	24.50 N	59.60 W
12 February 98 22:42 GMT	24.50 N	61.10 W
13 February 98 10:48 GMT	24.50 N	62.20 W
13 February 98 22:45 GMT	24.50 N	63.30 W
14 February 98 22:46 GMT	24.50 N	65.90 W
15 February 98 10:50 GMT	24.50 N	66.90 W
15 February 98 22:47 GMT	24.50 N	68.40 W
16 February 98 11:1 GMT	24.90 N	69.40 W
16 February 98 22:37 GMT	25.50 N	70.00 W
17 February 98 10:42 GMT	26.20 N	70.60 W
17 February 98 22:49 GMT	26.50 N	71.50 W
18 February 98 10:39 GMT	26.50 N	72.50 W
18 February 98 22:50 GMT	26.50 N	73.20 W
19 February 98 10:45 GMT	26.50 N	73.90 W
19 February 98 22:47 GMT	26.50 N	74.80 W
20 February 98 10:46 GMT	26.50 N	75.50 W
20 February 98 22:47 GMT	26.50 N	75.90 W
21 February 98 10:42 GMT	26.50 N	76.30 W
21 February 98 22:43 GMT	26.50 N	76.60 W
22 February 98 10:46 GMT	26.50 N	76.80 W

Table 2. AVHRR HRPT overpasses for the eastern part of the NOAA S *Ronald H. Brown* cruises at 24ºN. Supplied by Dr. F. Herrera the University of La Laguna, Tenerife, Canary Islands.

NOAA-14 on 1998-January-15 at 0433
NOAA-12 on 1998-January-15 at 0830
NOAA-14 on 1998-January-15 at 1551
NOAA-12 on 1998-January-15 at 1943
NOAA-14 on 1998-January-16 at 0422
NOAA-12 on 1998-January-16 at 0807
NOAA-14 on 1998-January-16 at 1540
NOAA-12 on 1998-January-16 at 1921
NOAA-12 on 1998-January-17 at 0746
NOAA-14 on 1998-January-17 at 0411
NOAA-14 on 1998-January-17 at 1529
NOAA-12 on 1998-January-17 at 1859
NOAA-12 on 1998-January-17 at 2040
NOAA-14 on 1998-January-18 at 0400
NOAA-14 on 1998-January-18 at 0541
NOAA-12 on 1998-January-18 at 0724
NOAA-12 on 1998-January-18 at 0904
NOAA-14 on 1998-January-18 at 1518
NOAA-14 on 1998-January-18 at 1700
NOAA-12 on 1998-January-18 at 1837
NOAA-12 on 1998-January-18 at 2017
NOAA-14 on 1998-January-19 at 0349
NOAA-14 on 1998-January-19 at 0530
NOAA-12 on 1998-January-19 at 0702
NOAA-12 on 1998-January-19 at 0842
NOAA-14 on 1998-January-19 at 1507
NOAA-12 on 1998-January-19 at 1955
NOAA-14 on 1998-January-20 at 0338
NOAA-12 on 1998-January-20 at 0820
NOAA-14 on 1998-January-20 at 1456
NOAA-14 on 1998-January-21 at 0327
NOAA-12 on 1998-January-21 at 0758
NOAA-14 on 1998-January-21 at 1445
NOAA-12 on 1998-January-21 at 1911
NOAA-14 on 1998-January-24 at 0434
NOAA-12 on 1998-January-24 at 0652
NOAA-14 on 1998-January-24 at 1553
NOAA-12 on 1998-January-24 at 1945
NOAA-14 on 1998-January-25 at 0423
NOAA-12 on 1998-January-25 at 0810
NOAA-14 on 1998-January-25 at 1542
NOAA-12 on 1998-January-25 at 1923
NOAA-14 on 1998-January-26 at 0412
NOAA-12 on 1998-January-26 at 0748
NOAA-14 on 1998-January-26 at 1530
NOAA-12 on 1998-January-26 at 1901
NOAA-14 on 1998-January-27 at 0401
NOAA-12 on 1998-January-27 at 0726
NOAA-14 on 1998-January-27 at 1519
NOAA-12 on 1998-January-27 at 1839
NOAA-14 on 1998-January-28 at 0350
NOAA-12 on 1998-January-28 at 0704
NOAA-14 on 1998-January-28 at 1508
NOAA-12 on 1998-January-28 at 1957
NOAA-14 on 1998-January-29 at 0339
NOAA-12 on 1998-January-29 at 0822
NOAA-14 on 1998-January-29 at 1639
NOAA-12 on 1998-January-29 at 1935
NOAA-14 on 1998-January-30 at 0509
NOAA-12 on 1998-January-30 at 0800
NOAA-14 on 1998-January-30 at 1628
NOAA-12 on 1998-January-30 at 1913
NOAA-14 on 1998-January-31 at 0458
NOAA-12 on 1998-January-31 at 0738
NOAA-14 on 1998-January-31 at 1616
NOAA-12 on 1998-January-31 at 2032
NOAA-14 on 1998-February-01 at 0447
NOAA-12 on 1998-February-01 at 0856
NOAA-14 on 1998-February-01 at 1605
NOAA-12 on 1998-February-01 at 2010
NOAA-14 on 1998-February-02 at 0436
NOAA-12 on 1998-February-02 at 0834
NOAA-14 on 1998-February-02 at 1554
NOAA-12 on 1998-February-02 at 1947
NOAA-14 on 1998-February-03 at 0425
NOAA-12 on 1998-February-03 at 0812
NOAA-12 on 1998-February-05 at 0909
NOAA-14 on 1998-February-05 at 1703
NOAA-12 on 1998-February-05 at 2022
NOAA-14 on 1998-February-06 at 0533
NOAA-12 on 1998-February-06 at 0846
NOAA-14 on 1998-February-06 at 1651
NOAA-14 on 1998-February-07 at 0522
NOAA-14 on 1998-February-08 at 0511

The M-AERI was mounted on the port side of the ship for the eastward-going first leg to avoid contamination of the data by sun-glint. It was moved to the starboard side for the westward-going second leg. During the port call the instruments were examined, cleaned and two M-AERI cables that showed signs of deterioration were repaired.

***Conclusions*:**

All instruments worked well and returned good quality data (Figure 3). Initial analysis of the skin

temperature effects shows characteristics similar to those found on earlier cruises in the Pacific Ocean, but more detailed analysis is expected to reveal differences in behavior from more varied ocean-atmosphere flux regimes.

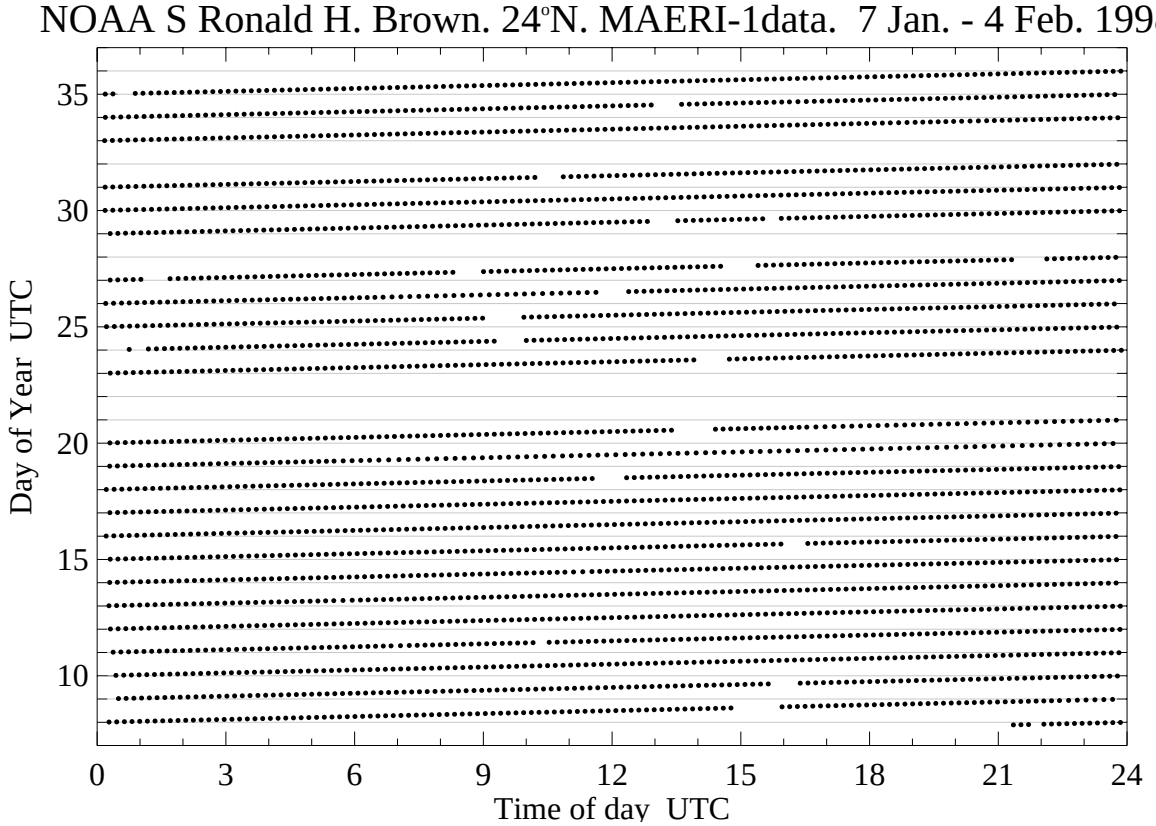

Figure 3. Infrared spectra measured by the M-AERI during the NOAA S Ronald H. Brown sections along 240N. Each dot represents the time at which an independently calibrated set of spectra were measured. Gaps in the sequence are attributable to instrumental problems, failures in the achieving procedure or periods of spray or precipitation requiring the instrument to be enclosed. [Preliminary data].

B.1.3 The North Water cruise of the *CCGS Pierre Radisson*

Objectives

To gain more ship-time experience with M-AERI's prior to the EOS-AM Launch; to gather data for the study of the thermal skin effect at the ocean surface, and b) diurnal temperature signals; to test satellite validation schemes using data from the AVHRR and ATSR.

Personnel involved

A.	Cruise Leg 1, from Quebec to the North Water	–Dr. P. J. Minnett
B.	Cruise Leg 2, in the North Water	–Ms. E. Key
C.	Cruise Leg 3, in the North Water	–Dr. P. J. Minnett
D.	Cruise Leg 4, in the North Water	–Ms. J. Hanafin

Narrative:

The Canadian Coast Guard ice-breaker Pierre Radisson left Quebec City on March 26 to head north to the area of the North Water Polynya between Greenland and Ellemere Island at the north of Baffin Bay

(abut 77°N, 75°W). The ship will remain in the area until late July to facilitate the study of the physics, chemistry and biology of the polynya throughout its development from late winter to high summer. This period is divided into four cruises, and M–AERI (and other) measurements were made on all of these. This provides the opportunity to collect M–AERI data over a wide range of Arctic conditions. These will be used to validate AVHRR sea-surface temperatures through very dry, cold atmospheres. AVHRR data are being collected at a satellite data receiver installed at Alert on the north of Ellesmere Island by the Royal Military College of Canada[1]. In addition, it is planned that ATSR-2 data will also be compared with the M-AERI skin temperature measurements.

The M-AERI (model number 2) was mounted on the starboard side of the ship's foredeck, viewing ahead of the ship's bow-wave. A Coastal Environmental Systems Weatherpak was mounted on a 20' meteorological mast on the foredeck and near-continuous measurements of boundary layer meteorological parameters (Table 3) were made. These were augmented by measurements of upwelling short-wave radiation, reflected from the surface, from a down-pointing pyranometer mounted on a bowsprit extending about 15 feet beyond the bow of the ice-breaker. A surface float carrying a precision thermistor was deployed about 10 feet ahead, and inboard, of the M-AERI field of view. This was used to measure the bulk surface temperature at a depth of a few centimeters when the ship was on station and when ice conditions allowed.

Table 3. Measurements taken

Variable	Sensor	Comments
Skin Sea Surface Temperature	M-AERI	Continuous measurements
Skin Ice Surface Temperature	M-AERI	Continuous measurements
Infrared spectra of surface emitted radiation	M-AERI	Continuous measurements over range of angles. Pitch and roll measured to monitor ship's motion
Infrared spectra of atmosphere emitted radiation	M-AERI	Continuous measurements over range of angles. Pitch and roll measured to monitor ship's motion
Near surface bulk SST	Surface float	Only with ship on station; or making way in ice-free conditions
Bulk SST	Ship's Thermo-salinograph	Continuous measurements
Air Temperature	Thermistor	Continuous measurements
Relative humidity	Vaisala "Humicap"	Continuous measurements
Wind speed	R. M. Young anemometer	Continuous measurements
Wind direction	R. M. Young anemometer	Continuous measurements
Barometric pressure	Digital barometer	Continuous measurements
Insolation (SW_)	Eppley pyrometer	Continuous measurements Sensors gimballed to compensate for ship's motion.
Reflected (SW)	Eppley pyrometer	Continuous measurements.
Incident thermal radiation (LW)	Eppley pyrgeometer	Continuous measurements Sensors gimballed to compensate for ship's motion.
Cloud type and cover	All-sky camera	Continuous measurements
Atmospheric humidity profiles	Radiosondes	Few per day
Atmospheric temperature profiles	Radiosondes	Few per day

[1] (see http://www.rmc.ca/academic/physics/www/staff/marsden/avhrr.html).

Radiosondes were launched to provide measurement of the atmospheric temperature and humidity profiles. Because of the lack of opportunity to replenish the balloon gas (helium) throughout the expedition, launches were restricted to cloud-free situations when the conditions for infrared measurement of sea-surface temperature from satellite were good (Table 4).

Table 4. NOW 98 *Pierre Radisson* Radiosonde profiles

Date	Time	Lat	Lon	Termination	
				m	hPa
18 APR 98	15:09 GMT	77.34 N	76.50 W	22020	40.3
19 APR 98	1:16 GMT	77.00 N	76.83 W	20931	47.5
19 APR 98	23:48 GMT	76.00 N	77.17 W	21315	44.8
22 APR 98	1:32 GMT	77.05 N	77.35 W	19997	54.8
23 APR 98	18:28 GMT	76.30 N	74.67 W	21942	40.3
28 APR 98	16:46 GMT	77.00 N	77.53 W	21826	40.6
28 APR 98	22:28 GMT	77.00 N	77.53 W	20156	52.2
2 MAY 98	17:42 GMT	77.00 N	72.57 W	20345	51.3
25 MAY 98	15:22 GMT	76.96 N	73.76 W	17143	86.3
28 MAY 98	17:45 GMT	76.37 N	77.24 W	18148	75.2
28 MAY 98	20:46 GMT	76.34 N	77.11 W	21680	44.2
29 MAY 98	14:37 GMT	77.07 N	77.33 W	22741	37.8
29 MAY 98	17:15 GMT	77.02 N	76.23 W	21679	44.3
2 JUN 98	20:35 GMT	74.00 N	85.45 W	22180	41.3
4 JUN 98	15:44 GMT	75.22 N	74.95 W	22447	39.5
5 JUN 98	1:53 GMT	76.25 N	74.45 W	21777	43.8
6 JUN 98	2:08 GMT	76.28 N	74.75 W	21431	46.2
7 JUN 98	18:21 GMT	78.33 N	74.71 W	19909	57.7
8 JUN 98	2:19 GMT	78.35 N	74.65 W	20705	51.3
8 JUN 98	15:53 GMT	78.35 N	74.86 W	21389	46.2
18 JUN 98	17:40 GMT	76.97 N	74.44 W	20427	54.3
20 JUN 98	2:15 GMT	77.00 N	73.20 W	21269	47.9
28 JUN 98	2:26 GMT	75.47 N	69.98 W	22604	39.8
28 JUN 98	15:31 GMT	75.83 N	79.10 W	20950	50.9
29 JUN 98	1:03 GMT	75.83 N	79.10 W	22356	41.3
2 JUL 98	1:56 GMT	75.11 N	74.99 W	19178	66.2
4 JUL 98	1:04 GMT	76.25 N	74.08 W	21780	44.6
5 JUL 98	0:39 GMT	73.30 N	70.20 W	13143	161.9
7 JUL 98	1:04 GMT	76.25 N	74.15 W	21990	42.9
9 JUL 98	0:57 GMT	76.40 N	77.50 W	23035	36.9
13 JUL 98	0:42 GMT	78.33 N	74.50 W	10184	248.1
17 JUL 98	17:08 GMT	76.99 N	72.43 W	21970	44.3
18 JUL 98	18:09 GMT	76.95 N	74.97 W	23107	37.4
20 JUL 98	18:34 GMT	76.28 N	71.02 W	22888	38.3
21 JUL 98	18:22 GMT	76.26 N	74.16 W	19524	63.7
22 JUL 98	18:38 GMT	76.25 N	74.20 W	12315	183.0

An all-sky camera was installed above the bridge to record the cloud conditions throughout the cruise.

The track of the ship is shown in Figure 4.

The M-AERI was assembled on the passage north from Quebec and data acquisition began on March 28 and continued throughout the expedition (Figure 5). Data loss on April 4-5 was caused by very cold air temperatures chilling the instrument below its operating temperature. Improved insulation and installing a heater inside the external case of the instrument prevented subsequent data loss, even in colder temperatures. As with other M-AERI deployments the instrument was covered by a tarpaulin when spray or precipitation threatened to contaminate the scan mirror.

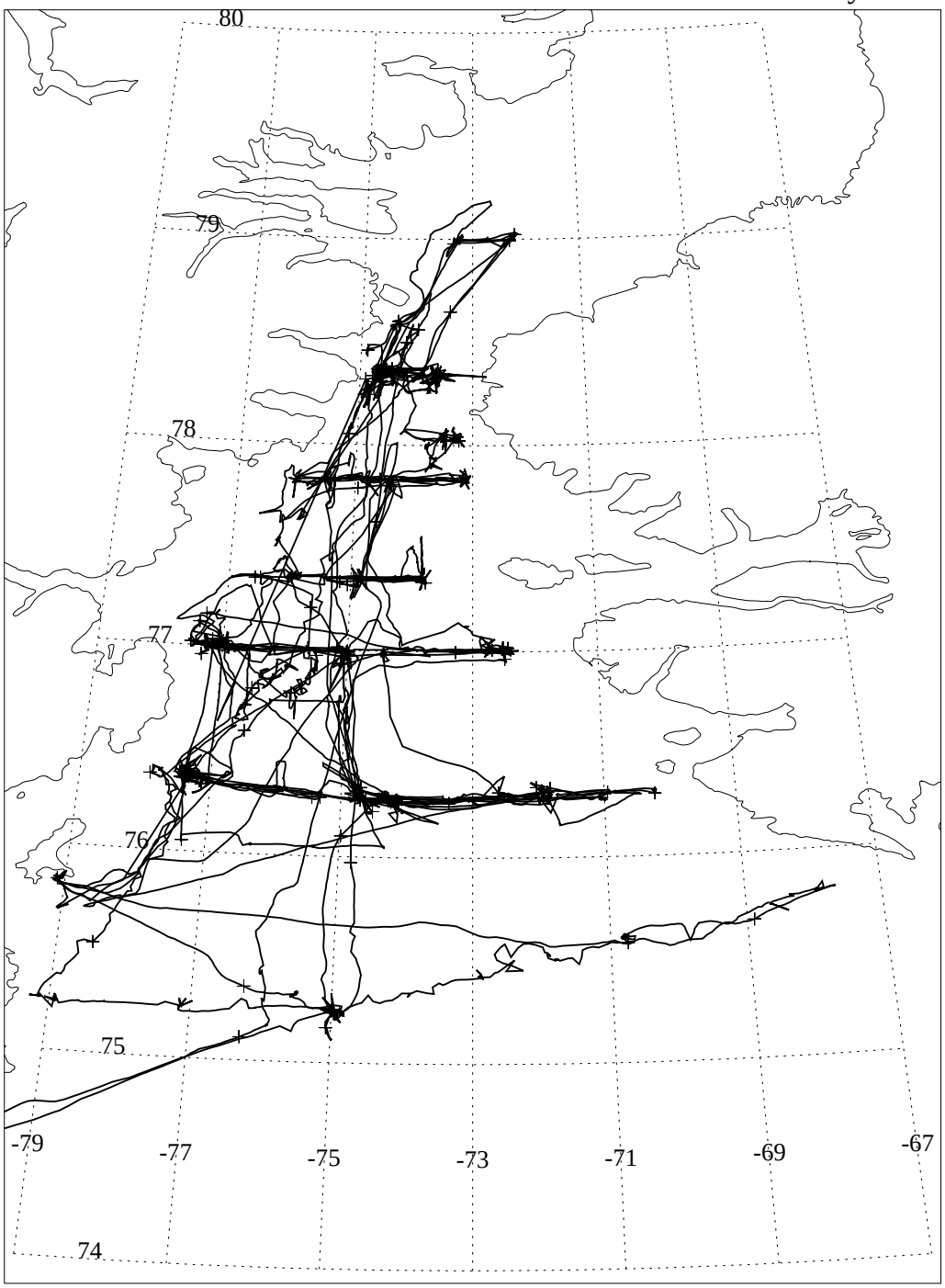

Figure 4. Track plot of the CCGS Pierre Radisson during the four legs of the North Water Polynya expedition.

A pair of Heimann KT-19 infrared thermometers were run continuously (small data loss was caused by cabling problems and a computer disk crash) to provide measurements of sky and surface infrared emission at the M-AERI view angles. These will be used to quantify the effects of clouds on the M-AERI measurements and characterize the surface in terms of open water and ice-cover.

Video recordings of the surface conditions were also made periodically to help in the interpretation of the M-AERI data.

Surface skin temperatures (sea and ice) were derived in real-time from the M-AERI measurements at a wavelength of 7.7μm.

***Conclusions*:**

The M-AERI can operate successfully in the extreme cold of the Arctic marine environment (air temperatures to -25^{0}C), but a better housing needs to be constructed for this to be done reliably.

Even in very cold water, when the bulk temperature was measured at freezing point, the skin temperature was found to be a few tenths of a degree colder.

Future Activities

An invitation was extended to participate in a short (two-week) cruise on another Canadian ice-breaker through the Northwest Passage in September, but the logistical difficulties of getting people and equipment to the High Arctic at relatively short notice and at a time when another cruise is underway, prevented us from accepting this offer.

A workshop will be held at the University of Manitoba in late August to coordinate data exchange and collaborative research amongst the cruise participants.

Plans are being made to mount a smaller expedition to the same area in summer 1999, which will provide an opportunity to validate MODIS SST retrievals. (Minnett's participation in these cruises is supported, in part, by another NASA grant for AVHRR validation, and by the NSF to measure the surface heat budget).

B.1.4 OACES cruise in the North Atlantic Ocean on the NOAA S *Ronald H. Brown*

Objectives

To make skin temperature measurements in mid-latitude and sub-tropical conditions. These will be used to study the thermal skin effect and diurnal temperature variations. They will also be used to test satellite validation schemes using the measurements of AVHRR. This data set is complimentary to that taken earlier in the year on the *Ronald H. Brown* (see B.1.1.).

Personnel involved

A. Cruise Leg 1, from Miami to Lisbon –Ms. J. Hanafin and Dr. W. McKeown (NRL-SSC)
B. Cruise Leg 2, from Lisbon to Ponta delGada –Dr. R. Sikorski and Dr. M. Szczodrak
C. Cruise Leg 3, from Ponta delGada to Miami –Dr. E. Kearns and Dr. A. Kumar

Figure 5. Infrared spectra measured by the M-AERI during the CCGS Pierre Radisson cruises in the North Water Polynya. Each dot represents the time at which an independently calibrated set of spectra were measured. Gaps in the sequence are attributable to instrumental problems, failures in the achieving procedure or periods of spray or precipitation requiring the instrument to be enclosed. [Preliminary data].

Narrative:

On May 8 the NOAA S*Ronald H. Brown* sailed from Miami at the start of the "GasEx '98" cruise of the Ocean-Atmosphere Carbon Exchange Study (Figure 6). This is a NOAA-sponsored investigation and consisted of a one-month cruise to the northeast of the Azores in which measurements were made of the transfer from ocean to atmosphere of an artificial tracer, injected with the upper ocean at the start of the experiment. As the solubility of many gases, including CO_2 in seawater is temperature dependent, measurement of the skin temperature is an important component of this study. Dr. P.J. Minnett was awarded NOAA funding to participate in this study using a M-AERI to determine the skin sea surface temperature.

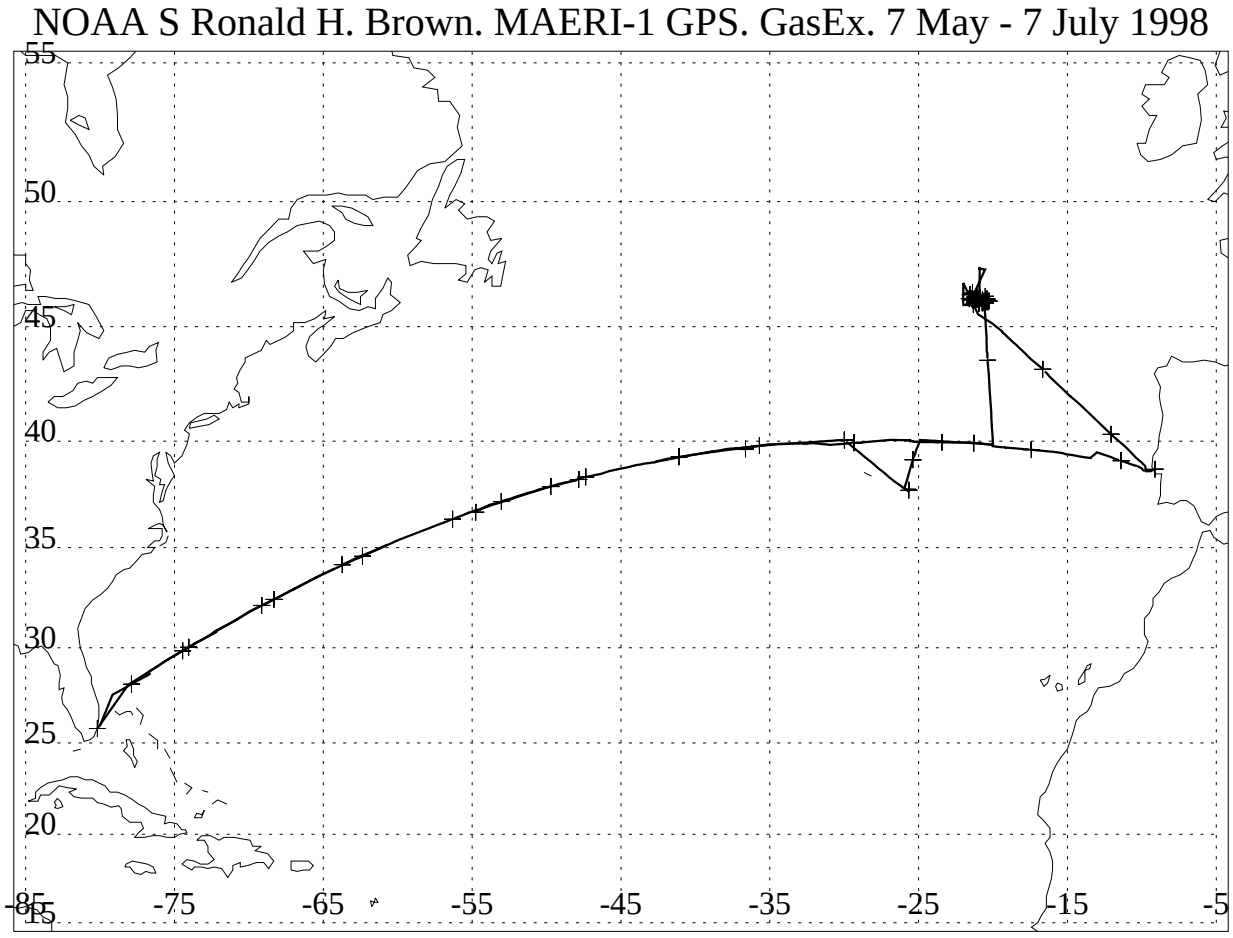

Figure 6a. Track plot of the NOAA S Ronald H. Brown during the three legs of the Gasex '98 cruise.

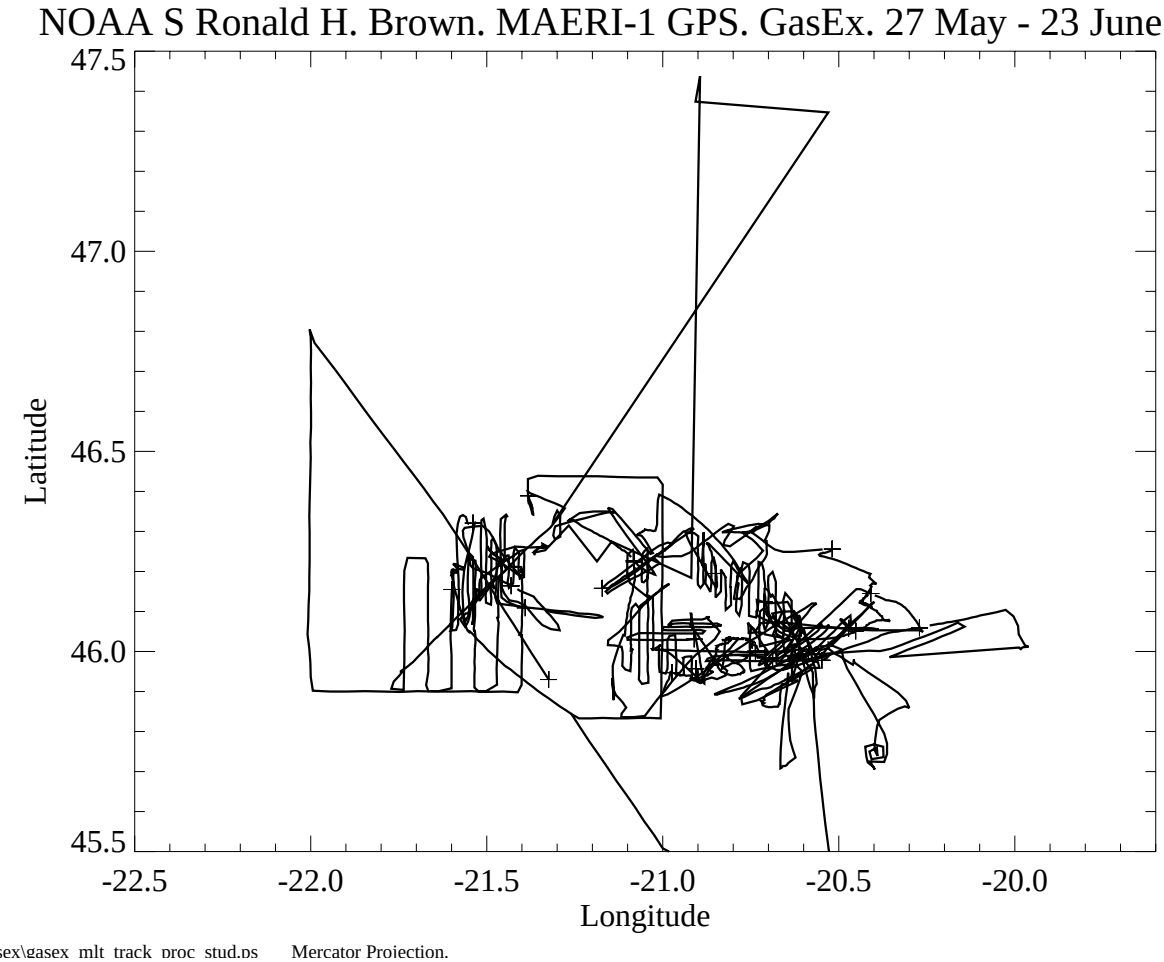

Figure 6b: Track plot of the NOAA S Ronald H. Brown during the process studies phase of the Gasex '98 cruise.

The expedition was divided into three legs, a transit from Miami to Lisbon, the month-long process study cruise starting in Lisbon and ending in Ponta delGada, Azores, and the transit from Ponta delGada to Miami.

The M-AERI was run throughout all three legs (Figure 7) and continuous bulk SST measurements were provided by the ship's thermosalmograph system. While the ship was on station a near-surface SST was measured using a thermistor in a surface-following float. Meteorological measurements were made by a number of cruise investigators, and radiosondes were launched to measure atmospheric temperature and humidity profiles.

Radiometric measurements of the skin temperature were made by other investigators (who were also involved in the Miami Infrared Radiometer Workshop - see below) so the cruise data should provide valuable information of the capabilities and merits of different instruments designed for the validation of satellite skin SST retrievals.

AVHRR data of the cruises in the eastern part of the Atlantic will be provided by Dr. Armando Fiuza of the Oceanographic Group at the University of Lisbon.

***Conclusions*:**

Real-time quality-assurance plots show that the M-AERI(01) functioned well during the cruise.

Figure 7. Infrared spectra measured by the M-AERI during the NOAA S Ronald H. Brown "GasEx" cruises in the N. Atlantic. Each dot represents the time at which an independently calibrated set of spectra were measured. Gaps in the sequence are attributable to instrumental problems, failures in the achieving procedure or periods of spray or precipitation requiring the instrument to be enclosed. [Preliminary data].

Future Activities

Following the port-call in Miami at the end of the GasEx '98 the *Ronald H. Brown* will sail for Newport, Oregon, passing through the Caribbean Sea, the Panama Canal, and the northeast Pacific Ocean. Space has been offered to the M-AERI group for equipment and people to remain on board for this transit. This offer has been accepted.

A workshop is planned for October 1998 in Miami for GasEx '98 project participants.

B.1.5 M-AERI Refinements.

Although both M-AERI 1 and M-AERI 2 performed well during the *Revelle* cruise a number of software and hardware improvements were identified. Following discussions with the M-AERI designers at SSEC - U. Wisconsin, some of these are being developed upon for inclusion in the M-AERI 3 and for retro-fit on M-AERIs 1 and 2. In addition to correcting some software bugs that have come to light with more extensive use, these refinements include higher capacity disk drives, software improvements to alert the user to anomalous instrument status and software refinements to make single-operator control less burdensome.

B1.6 Miami Workshops.

Two international workshops were held sequentially at RSMAS during early March. The first, from March 2 to 4, was designed to provide the opportunity for researchers using quantitative infrared radiometry to validate satellite retrievals to compare to calibrate their instruments in the laboratory against standard blackbody targets, to compare field-deployable black-body targets against reference standards, and to compare the data from the various radiometers taken under conditions similar to those at sea by mounting them on the roof of the Marine Science Center at RSMAS. The second workshop, on March 5 and 6, was under the auspices of the Committee on Earth Observation Science and was focused on coordinating the efforts of various groups intending to use infrared radiometry to validate current and planned satellite instruments, over land as well as sea. The participants at the workshops represented groups in Australia and the UK as well as the US (see Table 5), and the instruments they brought are listed in Tables 6 and 7.

Table 5.

Workshop Participants

Name	Address	Telephone	Fax	Email address
Dr. Ali Abtahi	Jet Propulsion Laboratory MS 183-501 4800 Oak Grove Drive Pasadena CA 91109	+1 818 354 5353	+1 818 354 0966	

Name	Address	Telephone	Fax	Email address
	USA			
Dr. Ian Barton	CSIRO Marine Labs PO Box 1538 Hobart Tasmania 7001 Australia	+61 3 62325481	+61 3 62325123	
Dr. Fred Best	Space Science and Engineering Center University of Wisconsin 1225 W. Dayton St. Madison WI 53706 USA	+1 608 263 6777	+1 608 263 6738	
Dr. Otis Brown	RSMAS-MPO University of Miami 4600 Rickenbacker Causeway Miami FL 33149 USA	+1 305 361 4000	+1 305 361 4711	
Dr. Jim Butler	NASA GSFC Code 920.1 Greenbelt MD 20771 USA	+1 301 286 4606	+1 301 286 1616	
Dr. Craig Donlon	CCAR. University of Colorado Campus Box 431 Boulder CO 80402 USA	+1 303 492 0955	+1 303 492 2825	
Jennifer Hanafin	RSMAS-MPO University of Miami 4600 Rickenbacker Causeway Miami FL 33149 USA	+1 305 361 4628	+1 305 361 4622	
Dr. Andy Harris	UK Met Office Rm. R 319 London Road Bracknell Berkshire, RG12 2SZ UK	+44 1344 854527	+44 1344 854412	
Dr. Andy Jessup	Applied Physics Lab. University of Washington 1013 NE 40th St Seattle WA 98105-6698 USA	+1 206 685 2609	+1 206 543 6785	
Dr. Carol Johnson	NIST	+1 301 975 2322	+1 301 869 5700	

Name	Address	Telephone	Fax	Email address
	B204/221 Gaithersburg MD 20899 USA			
Bob Kannenberg	NASA GSFC. MODIS Admin. Support Team Code 922 Greenbelt MD 20771 USA	+1 301 286 4625	+1 301 286 1757	
Dr. Bob Knuteson	Space Science and Engineering Center University of Wisconsin 1225 W. Dayton St. Madison WI 53706 USA	+1 608 263 7974	+1 608 263 6738	
Dr. Walt McKeown	Naval Research Lab. Oceanography Division Code 7340 Stennis Space Center MS 39529 USA	+1 601 688 5456	+1 601 688 4149	
Dr. Peter Minnett	RSMAS-MPO University of Miami 4600 Rickenbacker Causeway Miami FL 33149 USA	+1 305 361 4104	+1 305 361 4622	
Dr. Tim Nightingale	Rutherford Appleton Lab. R25, 2-30 Chilton Didcot Oxfordshire, OX11 0QX UK.	+44 1235 445688	+44 1235 445848	
Dr. Frank Palluconi	Jet Propulsion Laboratory MS 183-501 4800 Oak Grove Drive Pasadena CA 91109 USA	+1 818 354 8362	+1 818 354 0966	
Dr. Fred Prata	CSIRO Division of Atmospheric Research PMB 1 Aspendale Vic 3195 Australia	+61 3 9239 4681	+61 3 9239 4444	
Dr. Joe Rice	NIST Bldg. 221, Rm. B208 Gaithersburg	+1 301 975 2133	+1 301 975 2950	

Name	Address	Telephone	Fax	Email address
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Dr. Goshka Szczodrak	RSMAS-MPO University of Miami 4600 Rickenbacker Causeway Miami FL 33149 USA	+1 305-361-4996	+1 305-361-4622	
Tom Sheasby	EOS Group University of Leicester Leicester Leicestershire LE1 7RH UK	+44 116 2525264	+44 116 2525262	
Dr. E. Theocharous	National Physical Laboratory Teddington TW11 OLW UK	+44 181 943 6977	+44 181 943 6935	
Dr. Gary Wick	Campus Box 449 University of Colorado Boulder CO 80309 USA	+1 303 492 6466	+1 303 492 2468	

Table 6. Details of instruments at Workshop

A. Radiometers

Participant	Name	Wavelength range	Aperture size (diameter)	Beamwidth (full angle)
Ian Barton	CSIRO radiometer			
Ian Barton	TASCO radiometer			
Craig Donlon	SOSSTR	8-12 μm	100x50mm	~10deg
Andy Jessup	Heimann KT19	8 - 14 μm	39mm	~4 deg
Andy Jessup	Heimann KT15	8 - 14 μm	20mm	~4 deg
Andy Jessup	Everest 4000.4GL	8 - 14 μm	10mm	~4 deg
Andy Jessup	Amber Radiance HS imager	3 - 5 μm		
Peter Minnett	M-AERI	3-18 μm	~5cm	32 mrad
Peter Minnett	Heimann KT19 (x2)	9.6 - 11.5 μm	39mm	~4 deg
Tim Nightingale	SISTeR radiometer			13 degr
Frank Palluconi	Broadband Field radiometer	8 - 14 μm	12.7mm	15deg
Fred Prata	5-ch filter radiometer (AHDS)	8 - 12 μm	55mm	50mrad (4deg)
Fred Prata	TASCO radiometer	8 - 12 μm	14mm	200mrad (4deg)
Fred Prata	EVEREST radiometer	8 - 14 μm	30mm	70mrad (4deg)

Table 7. B. Black Body calibration targets

Participant	Name	Temperatures	Aperture size
Ian Barton	Portable BB		
Craig Donlon	CASOTS BB		
Carol Johnson	NIST WBBB	20C & 30 C	10cm dia
Andy Jessup	APL Water bath BB - similar to NIST		
Robert Knuteson & Fred Best	M-AERI BB		
Frank Palluconi	Water bath BB	0 - 50 C	6cm dia
Tom Sheasby	CASOTS BB		

There were two activities in the first workshop - laboratory measurements by the radiometers of the six black-body calibration targets and comparisons of measurements of the sea-surface temperature in Bear Cut of Biscayne Bay made by the various radiometers from the roof-top instrument platform. These data are currently being analyzed and will be discussed in subsequent reports.

A World Wide Web page has been set up at RSMAS (http://www.rsmas.miami.edu/ir/) which is being used for information exchange between the participants. The minutes and conclusions of the RSMAS-CEOS workshop are also available at http://www.rsmas.miami.edu/ir/ceos-minutes.html. Robert Kannenberg of the MODIS Administrative Support Team attended the workshops and is preparing an article for the *Earth Observer* on these workshops. This article can be seen at http://www.rsmas.miami.edu/ir/IRWkshp.PDF

As a result of these workshops, Dr. P. Minnett submitted a proposal on behalf of a number of US investigators, to the European Space Agency for the validation of the SST retrievals from the Advanced Along-Track Scanning Radiometer (AATSR) on the European "Envisat" satellite planned for launch in May 2000. For details of the Envisat mission see http://envisat.estec.esa.nl.

B.1.7 Post launch validation cruises

As a result of the delay in the launch of the EOS AM-1 platform several cruises which were planned for post-launch MODIS validation will now take place before MODIS becomes operational in orbit. In addition to those described in earlier reports, a new cruise opportunity has arisen in September of 1998 on board the *R/V Melville* in the tropical eastern Pacific Ocean. The ship will sail from San Diego to recover some surface moorings in the Equatorial Pacific, returning to San Diego on September 30.

The planned M-AERI cruises are:

a) *RV Melville* - September 1998. Eastern Pacific Ocean.

b) *USCGC Polar Sea* -November-December 1998. Pacific Ocean , from Seattle to New Zealand.

c) *RV Mirai* -- summer 1999. Tropical Western Pacific Ocean.

d) *PFS Polarstern* -- December 1999. Atlantic Ocean from Bremerhaven to Cape Town.

The tracks of completed and planned cruises are shown in Figure 8.

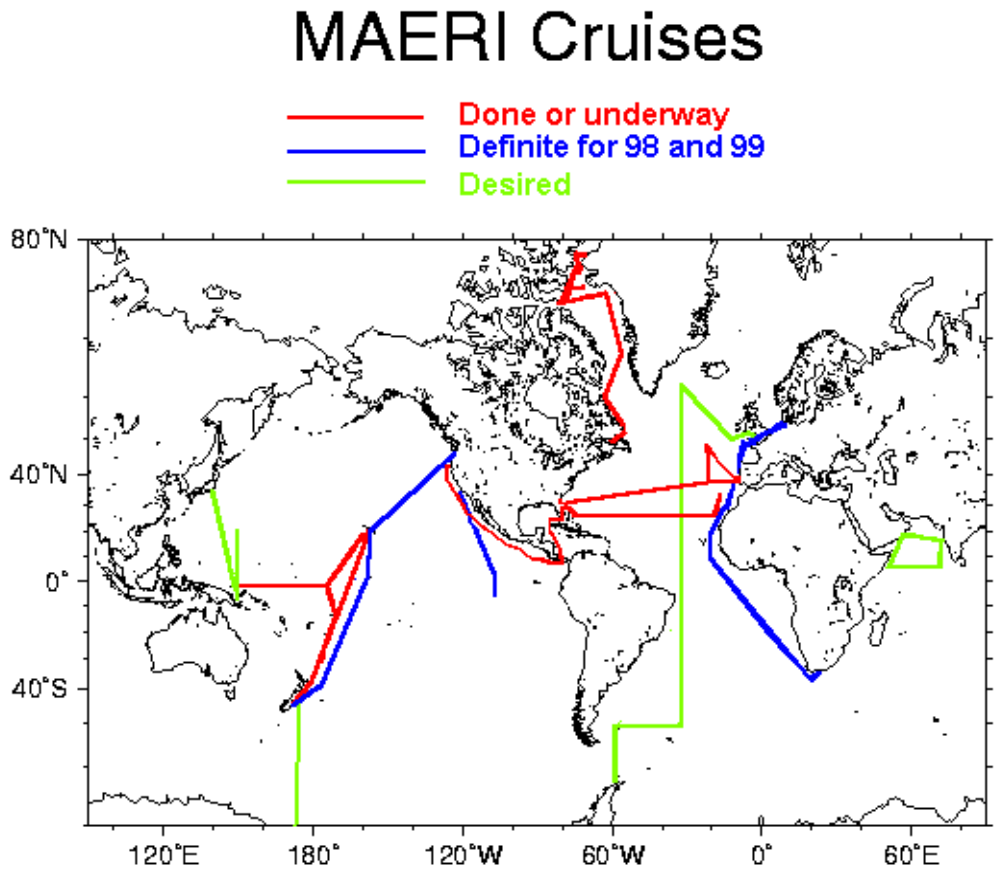

Figure 8. Completed and planned M-AERI cruises.

B.1.8 Wide Area Networking

DS3 circuit to VBNS via FloridaNet is up and in operation. PNNI-1 is configured and sharing route information with UFL and FSU. A second T1 to NSI was installed and is in operation. We are currently testing both paths.

C. Investigator Support

January	W. Baringer	A. Mariano
	J. Brown	R. Sikorski
	O. Brown	J. Splain
	K. Kilpatrick	S. Walsh
	A. Li	D. Wilson-Diaz
February	W. Baringer	A. Mariano
	J. Brown	R. Sikorski
	O. Brown	J. Splain
	M. Graham	S. Walsh
	K. Kilpatrick	
March	W. Baringer	K. Kilpatrick
	J. Brown	R. Kolaczynski
	O. Brown	J. Splain
	R. Jones	S. Walsh

April	W. Baringer	R. Kolaczynski
	J. Brown	A. Mariano
	O. Brown	G. Szczodrak
	K. Kilpatrick	S. Walsh
May	W. Baringer	A. Mariano
	O. Brown	G. Szczodrak
	M. Graham	S. Walsh
	R. Kolaczynski	
June	W. Baringer	R. Kovach
	E. Böhm	A. Mariano
	J. Brown	J. Splain
	O. Brown	G. Szczodrak
	K. Kilpatrick	S. Walsh
	R. Kolaczynski	

D. Future Activities

D.1 Algorithms

a. Continue to develop and test algorithms on global retrievals
b. Evaluation of global data assimilation statistics for SST fields
c. Participate in research cruises
d. Analyze data taken at radiometer and validation workshops
e. Continue radiative transfer modeling using RAL code
f. Continue analysis of research cruise data
g. Continue to study near-surface temperature gradients
h. Continue planning of post-launch validation campaigns
i. Validation Plan updates (as needed)
j. EOS Science Plan updates (as needed)
k. Define and implement an extended ATM based network test bed
l. Continued integration of new workstations into algorithm development environment
m. Continued participation in MODIS Team activities and calibration working group

D.2 Investigator support

Continue current efforts.

E. Problems

No new problems to report.

F. Publications and Presentations

Robert Evans, Richard Sikorski and Peter Minnett are co-authors on an invited keynote presentation entitled, "Pathfinder Retrieval Accuracy and Effects of Water Vapor" given at the Spring AGU Meeting in Boston, on May 29, 1998.

Peter Minnett gave an invited presentation at the IEEE International Geoscience and Remote Sensing Symposium in Seattle on July 6, 1998. The paper was entitled, "At-sea measurements of the ocean skin temperature and its response to surface fluxes" by P.J. Minnett and J. Hanafin.